Numerical Investigation of the Vortex Induced Motion of SPAR in Uniform Current

Weiwen Zhao, Zhirong Shen, Decheng Wan
State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China

ABSTRACT

As the development of model ocean engineering techniques, Spar offshore platforms have been widely used in the area of deepwater drilling. Vortex Induced Motions (VIM), as a common phenomena of Spar platforms exposed to flow, is one of the main factors that affect the lifecycle of offshore platforms and should be avoided as much as possible in the design stage. Two common effective ways to mitigate VIM are the configuration of helical strakes and the adjustment of mooring line stiffness. The former could change the flow pattern in the vicinity of Spar hull and the latter can change the eigenfrequency of platforms in still water to avoid resonance frequency. There have been many investigations on Spar VIM both numerically and experimentally. In this paper, VIM of bared cylinder and straked Spar are compared numerically in uniform current at model scale and at different Reynolds numbers. Fundamental study of VIM is done by comparing motion amplitude at different reduced velocity. To predict the motion of Spar, a spring model is employed. To capture the detailed eddy information of the flow, Large Eddy Simulation (LES) is applied. All the simulation are done at a model scale (1:60).

KEY WORDS: Large Eddy Simulation; Spar; Vortex Induced Motions; OpenFOAM

INTRODUCTION

Spar type offshore platforms are commonly installed in the Gulf of Mexico (GoM). Due to the bluff, vertical columnar hull shape, Spar is subject to VIM when exposed to currents. VIM has a great impact on the lifecycle of Spar platforms, especially the fatigue and wear issues of mooring system.

When vortex sheds at a frequency $f_o$ near eigenfrequency $f_0$ in still water, the cylinder oscillates violently and the motion amplitude can approach one diameter. Helical strakes were hence designed to reduce the VIM of Spar by interrupt the formulation of vortex near hull.

There have been a lot of publications on Spar VIM in decades. Dijk et al. (2003) did several model tests in MARIN. The objective is to evaluate the Vortex Induced Vibration (VIV) response of truss Spars and to optimize their strake configurations. Smith et al. (2004) studied the effects of loop / eddy current on Spar VIM and the fatigue and wear issues for mooring systems of Spars subject to VIM. Halkyard et al. (2005) made a benchmarking of Truss Spar VIM with CFD and experiments. The focus was on the effect of current direction, reduced velocity and strake pitch on the VIM response. The works were done using a finite element code AcuSolve. Atluri et al. (2006) simulated a Truss Spar model at model scale 1:40 which was focus on the hydrodynamic effects on Spar VIM introduced by holes on strakes and hull appendage. Their works were also done with AcuSolve. Shriram et al. (2006) applied a new generation of LES type model for the simulation of flow around a Spar hull. This new method involved a Variational Multiscale formulation, allowing better capture of the back scatter. And the simulation was compared with experimental data from a model test. Finnigan and Roddier (2007) did some model tests at Super Critical Reynolds Numbers. The effects of appurtenances and current heading on strake effectiveness and VIM response were discussed. Oakley Jr. and Constantinides (2007) tested a newly developed meshing techniques and seeking an understanding of how spar appurtenances interact. The model have a high fidelity, and many details like strakes, pipes, chains and anodes were included. The existence of strakes and more complex geometry such as appurtenances are the main reason that there are currently no effective analytical method for predicting Spar VIM. This paper aims at the initial strakes design for Spar platform, and testing the capability of CFD working condition in predicting Spar VIM.

There were also several numerical investigation of flow over a cylinder or cylinders. Liang and Wan (2009) had some numerical investigations of cylinder transversely forced oscillation in uniform current with low Reynolds number at 200. The work was focused on the hydrodynamic forces on the cylinder, as well as the wake pattern change of vortex shedding. Cao and Wan (2010) studied the numerical simulation of the flows around single and two circular cylinders in tandem arrangement by OpenFOAM solver. The Reynolds numbers were at a range of 100-300. Duan and Wan (2013) studied a three-dimensional simulation of flow around a cylinder at Reynolds number of 3900. The works were done by applying LES turbulence approaches provided by OpenFOAM solvers. The numerical results showed good agreement with the experimental ones.

In this paper, we present two models to study the fundamental